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天津 1∶50 000 黄庄公社幅地质图数据库

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摘要：天津 1∶50 000 黄庄公社幅 (J50E004015) 地质图在充分收集利用已有地质资料的基础上，根据行业规范要求，采用数字填图系统进行地质填图及数据库建设。数据库包含基本要素、综合要素、对象要素和独立要素等 4 个数据集，共计 23 种数据类型，数据量为 43.8 MB，其中地质体面实体数据 96 个、地质 (界) 线数据 320 条、摄像 (照片) 数据 85 个、同位素测年数据 9 个、钻孔数据 10 个，沉积（火山）岩石地层单位数据 13 个。地质图总结了浅表沉积物地貌成因类型及其垂向地质结构、上新世晚期以来的地层结构特征及岩相古地理演化、基岩地质构造、环境工程地质问题，同时探索了沿海低平原覆盖区地质调查工作方法和地质图的创新图面表达方式，为覆盖区区域地质调查起到了示范作用。本数据库可以为地质环境保护，自然资源管理，水文、工程、环境地质调查提供详实的基础地质资料，能够支撑国家重要经济区可持续发展、重大工程建设与地质环境保障、城市规划和生态环境保护。

关键词：天津；黄庄公社幅；1∶50 000；数据库；低平原覆盖区；第四纪；地质调查工程

数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

天津地区地处华北盆地北部，渤海湾西岸 (图 1)，太古宙至中生代经历了基底形成，盖层发展和构造活化 3 个构造发展阶段 (闻秀明，2011)。新生代以来在新构造运动影响下持续沉降 (Xu QM et al.，2017，2018；高峰等，2017；黄猛等，2019；Yang JL et al.，2020)，形成了巨厚的松散沉积物。第四纪以来，受气候波动影响 (高秀林等，1986；范淑贤等，2010)，经历了多次海陆变迁，形成了典型堆积型海岸 (王强等，1983)。全新世中晚期以来，本区先后发生海进及阶段性海退，形成一套海侵沉积。海退过程中河流与海洋共同作用形成了牡蛎礁、贝壳堤，其分布基本与现今海岸线潮间带一致，大致呈环带状分布，且地貌年龄自陆向海有逐渐变年轻的趋势 (王强和李凤林，1983；王宏等，2006)。

天津地区地质调查研究工作开始于 20 世纪 50 年代，涉及基础地质调查、水文地质

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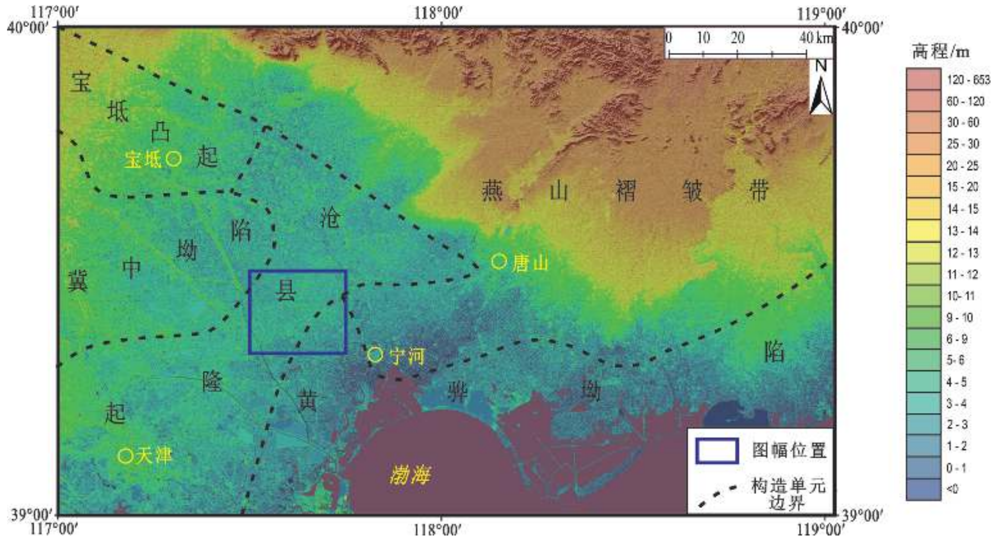

图 1　天津 1：50 000 黄庄公社幅大地构造位置图

调查、油气普查与勘探、煤田地质、地热普查与勘探、工程地质勘查等多个方面。不同学者对天津及周边地区的构造演化 (邓晋福等，2006；陈根文等，2008)、新生代岩相古地理 (林玉祥等，2015)、第四系沉积环境 (施林峰等，2009；王强和李从先，2009；胥勤勉等，2011；杨吉龙等，2015)、水文地质 (苗晋杰等，2008；杨耀栋等，2011)、工程地质 (王兰化等，2015)、地面沉降 (白晋斌和牛修俊，2010；吕潇文等，2017；郭海朋等，2017)、环境地质 (李建芬等，2010)、地热地质 (程万庆等，2012) 进行了研究。这些前期工作为本次区域地质调查提供了详实的地质资料，为地质图的编制奠定了基础。1：50 000 黄庄公社幅 (J50E004015) 地质图是中国地质调查局天津地质调查中心在滦河冲积扇–三角洲地区连片部署的 1：50 000 区域地质调查图幅之一，在系统收集、分析利用图幅内已有的区域地质、物探、化探、遥感等资料的基础上，采用数字填图、遥感解译、钻探、综合物探等多种技术，以第四纪地质结构和断裂构造为重点调查对象，开展 1：50 000 区域地质调查，查明了制约水文地质、工程地质、环境地质、灾害地质等问题的基础地质条件，并建立地质图空间数据库，为国家重要经济区可持续发展、重大工程建设和地质环境保障、城市规划和生态环境保护等提供支撑。天津 1：50 000 黄庄公社幅 (J50E004015) 地质图反映了新一轮区域地质调查工作中取得的地质调查和科研成果，探索和总结了平原区现代填图技术方法和成果表达方式，为提高调查区地质研究水平，地质理论创新和现代填图技术运用提供基础支撑和创新动力。天津 1：50 000 黄庄公社幅地质图数据库（黄猛等，2020）的元数据简表如表 1 所示。

2　数据采集和处理方法

2.1　数据采集

本次区域地质调查数据采集采用资料收集、遥感解译、数字高程模型解译、地质路线调查、人工槽型钻探、陡坎剖面测量、第四系地质钻探、样品采集与测试等多种工作手段完成。针对不同的调查目的采用不同的调查方法。针对服务于生态环境保护，主要调查中晚全新世地层和地质地貌特征，采用遥感、数字高程、路线、人工槽型钻和陡坎等调查手段；针对服务于水文地质，调查晚新生代地层格架及地层结构特征，实施

表 1　数据库 (集) 元数据简表

条目	描述
数据库(集)名称	天津市1∶50 000黄庄公社幅地质图数据库
数据库(集)作者	黄　猛，天津市地质调查研究院 陈　星，天津市地质调查研究院 王　莉，天津市地质调查研究院 马青云，天津市地质调查研究院
数据时间范围	2016—2018年
地理区域	东经117°30′ ~ 117°45′，北纬39°20′ ~ 39°30′
数据格式	MapGIS
数据量	43.8 MB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局地质调查项目“燕山—太行成矿带丰宁和天镇地区地质矿产调查”(项目编号: DD20160042)资助
语种	中文
数据库(集)组成	1∶50 000黄庄公社幅地质图数据库包括基本要素、综合要素、对象要素和独立要素等4个数据集，共计23种数据类型。基本要素数据集由地质体面实体、地质(界)线、样品、摄像(照片)、同位素测年、钻孔、河、湖、海、水库岸线等组成。综合要素数据集为标准图框(内图框)。对象要素数据集由沉积(火山)岩石地层单位、面状水域与沼泽、图幅基本信息组成。独立要素为图饰内容，包含综合柱状图、图切剖面、镶图、图例、接图表等

1 个 500 m 深的钻孔；针对服务区域工程地质，主要调查晚第四纪地层，实施 7 个 70 ~ 80 m 深的钻孔，2 个 20 m 深的钻孔。数据采集采用的地理底图由国家基础地理信息中心提供，比例尺为 1∶25 000，坐标系统为 1980 年西安坐标系，投影平面直角坐标，坐标单位为 m，1985 国家基准高程。

2.1.1　遥感解译

遥感解译选择了 1985 年 TM(thematic mapper) 影像数据、2002 年 ASTER 影像数据、2003 年 Landsat-7 卫星数据、2014 年资源三号卫星数据、2016 年 Landsat-8 卫星数据等 5 种不同时相、不同类型的影像数据源进行多波段融合解译。遥感数据处理及解译过程包括假彩色合成、几何校正、数据融合、影像镶嵌、遥感信息提取、建立解译标志、解译验证等。其中几何校正采用多项式方法校正，以 1∶50 000 地形图为底图，均匀采集控制点，进行正射纠正。每个图幅不少于 9 个控制点，与地面控制点间的拟合精度应控制在 2 个像元以内。遥感信息提取主要为线性影像信息提取和块状影像信息提取。采用目视解译法对古河道 (牛轭湖)、边滩、天然堤、决口扇、海滩脊、冲积扇、洼地等进行解译，采用以计算机监督分类为主、目视解译为辅的方法对第四系堆积物进行解译，建立微地貌、松散堆积物岩性等地质体解译标志。

2.1.2　数字高程模型解译

数字高程模型数据选择天津市测绘局 2000 年 1∶10 000 地形图 (等高距 1 m) 提取高程数据，剔除原始地质地貌分析的异常数据后，通过 ArcGIS 生成图幅数字高程模型 (DEM)，高程精度可达到 0.2 m。DEM 能够真实反映地貌及地貌组合特征，准确地反映不同区域的地貌形态、地貌轮廓、地势变化及地表切割等内容，充分弥补了天津滨海平原地区地质填图中地势平坦、坡度变化小、地貌不易区分的缺陷，能够对浅表沉积物进行更为细致的成因类型划分及垂向地质结构研究。

2.1.3　地质路线调查

地质路线调查目的是查明测区内第四纪地貌地质特征、地质环境现状和空间分布，填绘第四纪地貌地质图。野外地质路线调查全部采用掌上数字填图系统 (AoRGMap) 进行。野外 PRB 地质调查和整理过程均按《数字地质调查系统操作指南》(李超岭，2011) 工作指南及操作说明书进行操作。在数字填图系统中标绘出地质点 (P)、地质界线 (B) 及分段路线 (R) 等点、线信息，观察并录入各点的属性、沉积物、沉积构造等信息，初步建立数字填图 (PRB) 数据库。地质路线调查过程中，地质路线垂直于重要地质单元界线，要求每个地质单元至少有 2 ~ 3 条地质路线控制，路线间距及点距不采用平均工作量，根据地质复杂程度控制在 1 000 ~ 3 000 m，对重要地质体及地貌变化较大的区域沿走向进行一定追索。地质观测点主要布置在地质界线、地质体分布地段，岩性分界线、地质界线、重要接触关系、不同地貌单元及微地貌单元的分界线以及土壤与植被变化区段。

2.1.4　人工槽型钻探

路线调查中，采用槽型取样器全孔取心钻探，对浅表 3 ~ 5 m 进行了调查。浅表 5 m 以浅主要为晚全新世沉积，是研究晚全新世地质环境演化的关键层位，同时浅表 3 ~ 5 m 作为地球关键带，是土地利用、地下水补给及环境保护的关键。采用槽型取样器全孔取心取出的土心基本不受扰动，便于观察研究浅表松散沉积物的组成与结构构造，可以提供浅表松散沉积物成因类型等详细信息，对地层边界起一定的控制作用。

2.1.5　陡坎剖面测量

地质路线调查中，在砖厂等人工露头处进行剖面测量，选用比例尺一般为 1∶200，对于大于 20 cm 的地质体给予分层，对于小于 20 cm 但具有特殊意义地质体也予以重点描述并突出表示。在剖面中采集了^{14}C、微体鉴定等样品，查明了第四纪地质体与地貌类型的关系，根据物质成分及其所处的地貌部位划分填图单位，建立堆积层序；研究各类第四纪地质体形成时期及其与年代地层的对应关系。

2.1.6　第四系地质钻探

第四系地质钻探通过标准孔系统的岩心描述、样品采集和测试工作，对第四纪岩石地层进行划分，并建立工作区第四纪年代地层、磁性地层、生物地层、事件地层及气候地层层序，进行多重地层划分对比。岩心描述均在野外完成。将岩心放入直径为 10 cm 的聚氯乙烯 (PVC) 管中，剖开新鲜面，对颜色、物质组成、结构、构造、基本层序、地层接触关系、氧化还原特征、生物组成 (大化石) 等进行详细观察、记录与研究。同时在钻孔中系统采集古地磁、^{14}C 测年、微体古生物、综合样 (色度、碳酸盐、磁化率) 等测试样品。钻孔达到设计深度后进行自然电位、视电阻率、梯度电阻率、自然伽马测井，工作方法采用自下而上、自动、连续、恒速测量。

2.2　数据库建设流程

天津 1∶50 000 黄庄公社幅地质图数据库建设工作流程严格按照《数字地质图空间数据库》(DD2006-06) 建库标准与《数字地质调查系统操作指南》(李超岭，2011) 进行，数据库建设流程如图 2。

2.2.1　地质填图野外数据库

地质填图野外数据库包括野外手图库、野外总图 (PRB) 库和样品库。野外手图库是野外数字填图获取的第一手资料，野外路线采集内容包括地质点、点间路线、地质界

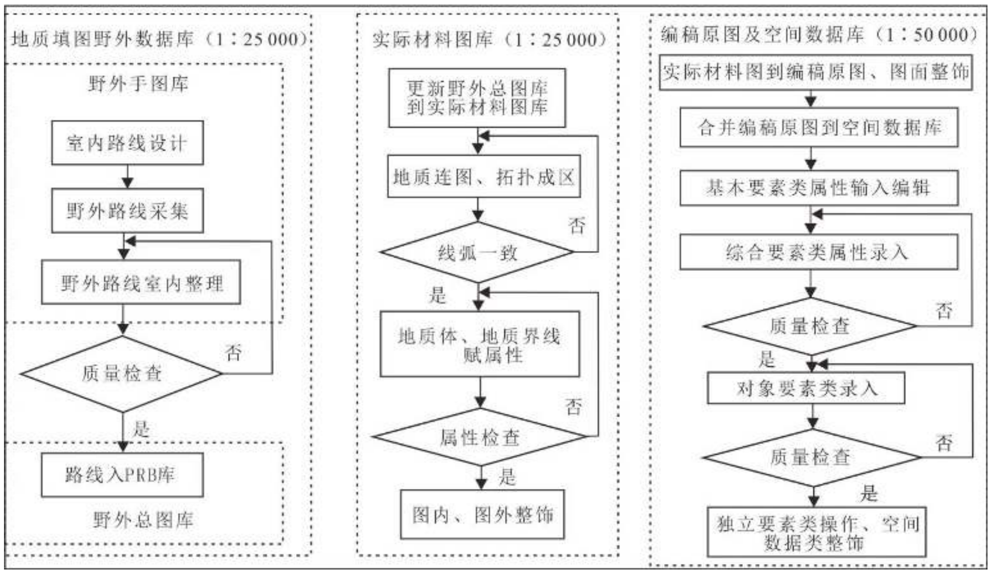

图 2　天津 1：50 000 黄庄公社幅地质图数据库建设流程图

线、素描、照片；室内路线整理包括地质点标注、照片、素描等整饰与标注。完成 PRB 数据的路线再在打开的图幅 PRB 库中逐条加入到野外总图库，形成野外总图 (PRB) 库，为确保资料收集的完备性、正确性和安全性，必须对野外地质路线 PRB 数据进行质量检查和数据备份。样品库包含野外工作所有样品信息，即采样信息、送样信息和测试成果，其中采样信息和送样信息在地质填图野外数据库阶段录入，测试成果则在实际材料图库阶段录入。

2.2.2　实际材料图库

实际材料图是集 PRB 数据原始性、综合性、可视性和动态性于一体的信息化图件，在图幅 PRB 库背景上编制而成。实际材料图的建库主要是针对地质区文件 (Geopoly.wp)、地质线文件 (Geoline.wl)、地质点文件 (Geolabel.wt) 这 3 个文件进行编辑。具体步骤如下：(1) 依据地质路线调查、人工槽型浅钻及陡坎剖面测量等资料，并结合遥感影像、DEM 影像特征，勾绘地质界线；(2) 拓扑关系处理；(3) 对 Geopoly.wp、Geoline.wl 进行属性赋值；(4) 按照设计书及用户需求设计、添加个性化图层。

2.2.3　编稿原图

编稿原图比例尺为 1：50 000，在 1：25 000 实际材料图基础上形成的。编稿原图的编辑工作主要是将 4 幅 1：25 000 实际材料图进行合并，具体工作如下: (1) 将 1：25 000 图幅接边处地质界线进行连接，将图幅内面状水体并入图中，对其进行拓扑错误检查，保证拓扑关系正确；(2) 将地质体界线拓扑后形成地质体面实体，通过合并标记 (label) 点，继承 1：25 000 实际材料图的面属性；(3) 对每一个地质体图元进行地质代号标注，对图例、图外附图、图表、图切剖面、接图表等内容进行整饰。该过程遵守相关标准规范，按照地质图出版要求，使编稿原图规范化、标准化。

2.2.4　地质图空间数据库

编稿原图经专家审核认定后，即进入空间数据库建设阶段，具体步骤为：(1) 自动合并编稿原图到空间数据库，空间数据库要素类数据自动继承编稿原图部分内容；(2) 采用人机互动的方式对图面拓扑一致性、地质要素表达及图面结构等进行检查，使其完全达到地质图及空间数据库建库要求；(3) 补充录入基本要素类属性数据；(4) 提取

综合要素类，并补充属性数据；(5) 提取对象类要素，并补充属性数据；(6) 录入对象类属性数据。

2.2.5　第四系钻孔数据库

本文共施工第四系钻孔 10 个，孔深 20 ~ 500 m 不等。在数据库建设过程中单独建立了第四系钻孔数据库。具体建库方法：(1) 在图幅 PRB 库界面下，新建第四系钻孔数据库，将钻孔数据以录入或导入的方式加入数据库；(2) 在系统自带数据库的基础上，将测井曲线、古地磁测试结果、综合样测试结果、地层时代、岩石地层划分等内容分别建立 ACCESS 数据库；(3) 对图名、图眉、表头、表体等部分内容进行整饰，使柱状图美观、实用，完成设计后，生成综合柱状图。

3　数据样本描述

天津 1：50 000 黄庄公社幅地质图数据库分为基本要素、综合要素、对象要素、独立要素等 4 个数据集。

3.1　基本要素数据集

天津 1：50 000 黄庄公社幅地质图数据库基本要素数据集包括地质体面实体 (_GeoPolygon)、地质 (界) 线 (_GeoLine)、样品 (_Sample)、摄像 (照片)(_Photograph)、同位素测年 (_Isotope)、钻孔 (_Drillhole)、(河、湖、海、水库) 岸线 (_Line_Geography) 等。

地质体面实体 (_GeoPolygon) 属性内容包括地质体面实体标识号、原编码、类型代码 (地质代码)、地质体名称、时代、下限年龄值、上限年龄值、子类型标识等，如表 2 所示。天津 1：50 000 黄庄公社幅地质图数据库中地质体面实体共包含 2 种类型，分别为沉积地层单位和面状水域与沼泽。其中沉积地层单位可划分河流沉积、三角洲沉积及海相沉积。河流沉积包含边滩、牛轭湖、天然堤、洪泛盆地、湖泊、沼泽等 7 个成因类型，三角洲沉积包含三角洲前缘和分流河道等 2 个成因类型，海相沉积包含海滩脊、越岸扇、高潮坪淡化潟湖等 4 个成因类型。河流沉积划归为歧口组，三角洲与海相沉积划归为高湾组。

表 2　地质体面实体属性表

序号	数据项名称	标准编码	数据类型	内容描述实例
1	标识号	*Feature_Id	Character	AJ50E004015000000049
2	原编码	Source_Id	Character	
3	类型代码	*Feature_Type	Character	Qhq$r$s
4	地质体名称	Geobody_Name	Character	全新世岐口组边滩沉积
5	时代	Geobody_Era	Character	Qh
6	下限年龄值/a.B.P	Geobody_Age1	Double	0
7	上限年龄值/a.B.P	Geobody_Age2	Double	2 500
8	子类型标识	Subtype	Integer	沉积(火山)岩石地层单位

注：$表示上角标。

地质 (界) 线 (_GeoLine) 属性内容包括要素标识号、原编码、代码 (地质代码)、类型、左侧地质体代号、右侧地质体代号、界面走向、界面倾向、界面倾角等，如表 3 所示。黄庄公社幅地质图数据库中地质 (界) 线类型包含不整合和水体接触 2 种类型。《数

字地质图空间数据库标准》(DD2006-06) 规定第四系与老地层及第四系地层单位之间接触关系为不整合接触，因此本数据库中不同沉积地层单位之间的接触类型均为不整合接触，面状水域与沉积地层单位间的接触类型为水体接触。

表 3　地质 (界) 线属性表

序号	数据项名称	标准编码	数据类型	内容描述实例
1	要素标识号	*Feature_Id	Character	AJ50E004015000000158
2	原编码	Source_Id	Character	
3	代码	*Feature_Type	Character	02
4	类型	Boundary_Name	Character	不整合
5	左侧地质体代号	Left_Boundary_Code	Character	Qhq$l$v
6	右侧地质体代号	Right_Boundary_Code	Character	Qhq$r$s
7	界面走向/°	Strike	Integer	330
8	界面倾向/°	Dip_Direction	Integer	60
9	界面倾角/°	Dip_Angle	Integer	1

注：$表示上角标。

样品 (_Sample) 属性内容包括要素标识号、原编码、编号、类型代码、类型名称、岩石名称、子类型标识等，如表 4 所示。黄庄公社幅地质图数据库中样品类型均为同位素年龄样，采用加速器质谱 (AMS) 碳-14 测试。

表 4　样品属性表

序号	数据项名称	标准编码	数据类型	内容描述实例
1	要素标识号	*Feature_Id	Character	AJ50E004015000000004
2	原编码	Source_Id	Character	D0095_3
3	样品编号	Sample_Code	Character	03
4	样品类型代码	*Feature_Type	Character	TW
5	样品类型名称	Sample_Name	Character	同位素年龄样
6	样品岩石名称	Rock_Name	Character	灰黑色黏土
7	子类型标识	Subtype	Integer	0

摄像 (照片)(_Photograph) 属性内容包括要素标识号、原编码、照片编号、照片题目、照片说明、子类型标识等。

同位素测年 (_Isotope) 属性内容包括要素标识号、原编码、样品编号、样品名称、年龄测定方法、测定年龄、所测定地质体单位及代号、测定分析单位、测定分析日期、子类型标识等，如表 5 所示。

钻孔 (_Drillhole) 属性内容包括要素标识、原编码、钻孔编号、钻孔深度、基岩或目的层孔深、基岩或目的层岩性、基岩或目的层时代、松散沉积层的年代、松散沉积层的分层厚度、松散沉积层的岩性、子类型标识等，如表 6 所示。黄庄公社幅地质图数据库中钻孔均为松散层钻孔，未钻遇基岩。根据目的层的不同可分为揭穿全新统、揭穿晚更新统、揭穿第四系等 3 类钻孔，孔深分别为 20 m，70 ~ 80 m 和 500 m，目的层时代分别为 Qp_3、Qp_2、N_2。

河、湖、海、水库岸线 (_Line_Geography) 属性内容包括要素标识号原编码、图元类型、图元名称、子类型标识等。

表 5　同位素测年属性表

序号	数据项名称	标准编码	数据类型	数据项描述
1	要素标识号	*Feature_Id	Character	AJ50E004015000000003
2	原编码	Source_Id	Character	D0095_2
3	样品编号	Sample_Code	Character	QHZ09-^{14}C02
4	样品名称	Sample_Name	Character	棕灰色黏土
5	年龄测定方法	Measuring_Kinds	Character	加速器质谱(AMS)碳-14测试
6	测定年龄/ a B.P.	Age	Character	5 360±30
7	所测定地质体单位及代号	Geobody_Code	Character	Qhg$b$r
8	测定分析单位	Unit	Character	美国BETA实验室
9	测定分析日期	Date	Character	2018-08-18
10	子类型标识	Subtype	Integer	0

注：$表示上角标。

表 6　钻孔属性表

序号	数据项名称	标准编码	数据类型	数据项描述
1	要素标识号	*Feature_Id	Character	AJ50E004015000000002
2	原编码	Source_Id	Character	QHZ04
3	钻孔编号	Zk_Code	Character	QHZ04
4	钻孔深度/m	Zk_Depth	Float	70
5	基岩或目的层孔深/m	Rock_Depth	Float	70
6	基岩或目的层岩性	Rock_Type	Character	灰黄色黏土、粉砂质黏土、黏土质粉砂，含较多钙质结核及潴育化斑块
7	基岩或目的层时代	Base_Bed_Era	Character	Qp@2
8	松散沉积层的年代	Loose_Lay_Era	Character	Qp@2
9	松散沉积层的分层厚度/m	Loose_Lay_Thickness	Float	70
10	松散沉积层的岩性	Loose_Lay_Lithology	Character	灰色、深灰色、棕黄色、灰黄色黏土、粉砂质黏土、黏土质粉砂、粉砂、细砂、中砂
11	子类型标识	Subtype	Integer	0

注：@表示下角标。

3.2　综合要素数据集

天津 1：50 000 黄庄公社幅地质图数据库综合要素数据集为标准图框 (内图框) (_MAP_FRAME.WL)，属性内容包括图名、图幅代号、比例尺、坐标系统、高程系统、左经度、下纬度、制图单位等。

3.3　对象要素数据集

天津 1：50 000 黄庄公社幅地质图数据库对象要素数据集由沉积 (火山) 岩石地层单位 (_Strata)、面状水域与沼泽 (_Water_Region)、图幅基本信息 (_Sheet_Mapinfo) 组成。

沉积 (火山) 岩石地层单位 (_Strata) 属性内容包括要素分类 (地质代码)、地层单位名称、地层单位符号 (地质体面实体代码)、地层单位时代、岩石组合名称、岩石组合主体颜色、岩层主要沉积构造、生物化石带或生物组合、地层厚度、含矿性、子类型标识等，如表 7 所示。黄庄公社幅地质图数据库沉积 (火山) 岩石地层单位名称为“时代+岩石地层单位+成因类型”的组合，如全新世高湾组海滩脊沉积 (Qhg^{br})，共包括 13 个地层单位，时代均为全新世 (Qh)。

表 7　沉积 (火山) 岩岩石地层单位属性表

序号	数据项名称	标准编码	数据类型	数据项描述
1	要素分类(地质代码)	*Feature_Type	Character	Qhg$b$r
2	地层单位名称	Strata_Name	Character	全新世高湾组海滩脊沉积
3	地层单位符号(地质体面实体代码)	Strata_Code	Character	Qhg$b$r
4	地层单位时代	Strata_Era	Character	Qh
5	岩石组合名称	Association_Name	Character	黏土质粉砂、粉砂及粉砂质黏土，含贝壳壳体及碎屑
6	岩石组合主体颜色	Color	Character	主要岩石的颜色
7	岩层主要沉积构造	Sedi_Structure	Character	交错层理、平行层理、透镜状层理、脉状层理
8	生物化石带或生物组合	Assemblage_Zone	Character	有孔虫、海相介形类、蛤类
9	地层厚度/m	Strata_Thickness	Character	0 ~ 3.0
10	含矿性	Commodities	Character	
11	子类型标识	Subtype	Integer	

注：$表示上角标。

面状水域 (_Water_Region) 属性内容包括要素分类代码、图元类型、图元名称、图元特征、子类型标识等。

图幅基本信息 (_Sheet_Mapinfo) 属性内容包括地形图编号、图名、比例尺、坐标系统、高程系统、左经度、右经度、上纬度、下纬度、成图方法、调查单位、图幅验收单位、评分等级、完成时间、出版时间、资料来源、数据采集日期。

3.4　独立要素数据集

天津 1：50 000 黄庄公社幅地质图数据库独立要素数据集主要为图面整饰内容，由综合柱状图 (COLOUM_SECTION)、图切剖面 (MAP_PROFILE)、图切剖面线 (PROFILE)、镶图 (XT)、第四系等深线 (DEPTH)、隐伏断裂 (HIDDEN_FAULT)、古海岸线 (PALEOCOAST LINE)、图例 (LEGEND)、接图表 (MAP_SHEET)、责任表 (DUTY_TABLE)、标注 (INDICIA) 等。

综合柱状图 (COLOUM_SECTION) 数据集主要内容为地质标准孔 QHJ01 多重地层特征以及浅表不同成因类型沉积物垂向地层结构特征。图切剖面 (MAP_PROFILE) 数据集主要内容为上新世晚期以来 (500 m 以浅) 三维地层结构特征。镶图 (XT) 数据集主要内容包括图幅大地构造位置、前新生界基岩地质图、上新世以来的岩相古地理演化图、地下水防污性能评价分区图、地面沉降等值线图、全新世高湾组软土分布范围图、潜在饱和砂 (粉) 土地震液化分布图及区域地壳稳定性评价图。第四系等深线 (DEPTH) 数据

集主要内容为图幅内第四系底界埋深变化特征。隐伏断裂 (HIDDEN_FAULT) 数据集主要内容为图幅内主要断裂展布特征。古海岸线（PALEOCOAST LINE）数据集主要内容为晚更新世以来不同海侵期古海岸线位置，第 I 海侵期可识别出 3 个不同时期的海岸线位置，距今时代分别为 5.5 ka.B.P、4.0 ka.B.P 和 2.5 ka.B.P，第 II 海侵期仅判断出最大海侵时海岸线的位置。

4 数据质量控制

天津 1∶50 000 黄庄公社幅地质图野外地质调查精度完全按照《区域地质调查总则 (1∶50 000)》(DZ/T 0001)、《1∶50 000 覆盖区区域地质调查工作指南 (试行)》及相关规范进行，调查精度满足区域地质调查工作的规范要求。野外 PRB 地质调查路线和整理过程均按《区域地质调查野外数据采集》工作指南及操作说明书进行操作。工作实施过程中注意 PRB 数据质量监控，强调数字化数据与原始资料的一致性和数字化精度的检查，所有地质数据均有原始数据备份和阶段性备份。数据库建设完全按照《数字地质图空间数据库标准》(DD2006−06)、《地质数据质量检查与评价》(DD2006−07) 及相关规范进行。

整个工作过程中野外原始资料自检、互检达 100%，项目组抽检大于 30%，符合地质调查项目质量管理要求。第四系地质钻探专门成立钻机管理小组，加强钻探施工过程质量管理，钻孔施工过程中聘请技术专家定期检查，对各项原始记录、技术资料进行全面检查。在项目内检的基础上，配合单位生产主管领导及上级管理单位进行野外和室内年度质量检查，按检查组要求及时解决图幅区内存在的地质问题。

天津 1∶50 000 黄庄公社幅地质图空间数据库于 2019 年 1 月 25—27 日通过了中国地质调查局天津地质调查中心组织的验收，评级为“优秀”级。

5 数据价值

天津 1∶50 000 黄庄公社幅地质图地质地貌调查充分利用多时相遥感、0.2 m 精度数字高程模型，结合槽型钻、路线调查，将浅表沉积物划分为河流、海侵等 2 个沉积体系。全新世中期发育海侵，形成三角洲和海退沉积。三角洲沉积分布在图幅北部，细分为三角洲前缘和三角洲分支河道等沉积；海退沉积分布图幅中南部，为海退过程形成，改造了三角洲沉积，细分为海滩脊、越岸扇、高潮坪、潟湖等沉积 (Xu QM et al., 2020)。河流沉积体系分布在图幅的东北部和西北部，包括有河道、堤岸和洪泛等沉积，切割改造三角洲和海侵沉积。在详细划分成因类型的基础上，总结了不同成因浅表沉积物的岩性组合及垂向演化特征，为水文地质分析大气降水入渗补给地下水资源和水源地环境保护提供了详细的基础地质支撑 (孟素花等，2011)。黄庄公社幅地质图在以往冲积、冲海积、海积等传统成因类型表达的基础上，进一步细化了填图单位，并选择典型钻孔柱状图标示浅表不同成因沉积物的垂向结构。同时将基岩地质图、新近纪以来的岩相古地理演化、地下水防污性能、地面沉降等值线、软土分布范围、潜在饱和砂 (粉) 土地震液化分布、区域地壳稳定性评价等图件作为镶图表达在地质图上，创新了地质图的图面表达。

深部地质调查通过施工地质标准孔 (QHJ01)，开展了岩石、年代、气候、生物、磁性等多重地层划分对比，总结了地层划分标志，建立了上新世晚期以来地层格架。结合

本次施工的第四系控制孔，盘活了水文地质钻孔资料，编绘多条剖面，反映了上新世晚期以来的三维地层结构特征。上新世晚期至中更新世，图幅内发育自东北向西南延伸的古滦河冲积扇–入湖三角洲沉积体系，是水源地勘查的目的层，查明了其空间展布和物质组成，为分析地下水的赋存空间和运移通道提供了基础数据 (王家兵，2013)。图幅内存在软土变形和饱和砂 (粉) 土地震液化等环境工程地质问题，查明了晚更新世以来发育 2 期海侵、古河道带沉积的空间分布及物质组成，初步总结了软土分布及饱和砂 (粉) 土地震液化的分布，为水文、工程、环境地质工作人员进一步调查研究这些问题提供了坚实的地质基础 (裴艳东和王国明，2016)。

根据获取的物探、钻孔等资料，基本查明了隐伏基岩地质构造，编绘了基岩地质图，圈定了寒武系—奥陶系岩溶热储层空间分布，为深部地热能资源调查和开发利用提供了地质基础 (刘杰等，2012)。

6 结论

(1) 天津 1：50 000 黄庄公社幅地质图在系统收集、分析利用图幅内已有的区域地质、物探、化探、遥感等资料的基础上，采用数字填图、遥感解译、钻探、综合物探等多种技术手段，对不同深度的晚新生代地层采取不同精度、不同方法进行了调查研究，对深部地质结构进行了系统总结，探索了沿海低平原覆盖区地质调查工作方法和地质图的创新图面表达方式，为覆盖区区域地质调查起到了示范作用。

(2) 在野外调查、分析研究、成果集成的基础上，按照数字地质图标准规范建立了天津 1：50 000 黄庄公社幅地质图空间数据库，包含基本要素、综合要素、对象要素和独立要素等 4 个数据集，共计 23 种数据类型，涉及地质体面实体、地质 (界) 线、样品、摄像 (照片)、同位素测年、钻孔、沉积 (火山) 岩石地层单位、综合柱状图、图切剖面、镶图等内容，全面反映了图幅内获取的研究成果。

(3) 天津 1：50 000 黄庄公社幅地质图空间数据库的建立为地质环境保护，自然资源管理，环境、工程、水文地质调查提供了详实的基础地质资料，能够支撑国家重要经济区可持续发展、重大工程建设和地质环境保障、城市规划和生态环境保护。

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Database of the 1∶50 000 Geological Map of Huangzhuang, Tianjin

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Abstract: 1∶50 000 geologic map of the Huangzhuang map-sheet (J50E004015), Tianjin was mapped by employing the Digital Geological Survey System (DGSS), and consequently a database was built by fully collecting and making use of existing geological data, as well as following industrial specifications. The database includes four datasets, i.e. a basic element, comprehensive element, object element and independent element, in total 23 different categories of data types, accumulating to a data size of 43.8 MB. Among them, there are 96 geological entities, 320 geological (boundaries) lines and 85 videos (photos), as well as nine samples of isotope dating, 10 boreholes and 13 sedimentary (volcanic) lithostratigraphic units. In the geologic map, the genetic type of the superficial deposit landform and its vertical geological structure, stratigraphic structure feature and lithofacies palaeogeographic evolution since the Late Pliocene, as well as the bedrock geological structure, and environmental engineering geological problems were all summarized; the methodology for the geological survey and innovative map presentation of the geologic map in the low coastal plain coverage area was explored simultaneously, which all play an exemplary role for regional geological survey in the coverage area. The database can provide detailed and basic geological data for geological environmental protection, natural resource management, in addition to hydrological, engineering and environmental geological surveying, thus supporting a sustainable development of an important national economic zone, major engineering construction, geological and ecological environmental protection, and urban planning.

Key words: Tianjin; Huangzhuang Map Sheet; 1∶50 000; database; low plain coverage; Quaternary; geological survey engineering

Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

The Tianjin area is located in the northern region of the North China Basin, along the

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Bohai Bay coast (Fig.1), which had experienced three tectonic stages from Archaean to Mesozoic, i.e. basement formation, cover deposition and tectonic activation (Wen XM, 2011). Since the Cenozoic, it had been continuously settled by a huge, thick and unconsolidated deposit under the influence of neotectonic movements (Xu QM et al., 2017, 2018; GAO F et al., 2017; Huang M et al., 2019; Yang JL et al., 2020). Since the Quaternary, it had been subjected to the influence of climatic fluctuation (Gao XL et al., 1986; Fan SX et al., 2010) and experienced several sea-land transformations, forming the typically accumulative coast (Wang Q et al., 1983). Since the Middle and Late Holocene, transgression and periodical regression had occurred successively in the area, resulting in a suite of transgressive deposit. During the regressions, rivers and oceans militated together, forming oyster reefs and shell ridges; distribution of which are basically the same to the intertidal zone of coastline nowadays. They were roughly distributed in the shape of annuluses and generally, the physiognomy age trended to be younger starting from the land to the sea (Wang Q and Li FL, 1983; Wang H et al., 2006).

A geological survey of Tianjin began in the 1950s, which involved a basic geological survey, hydrogeological survey, oil and gas survey and exploration, coal geology, geothermic survey and exploration, engineering geology exploration and many other aspects. Many scholars have studied tectonic evolution (Deng JF et al., 2006; Chen GW et al., 2008), Cenozoic lithofacies paleogeography (Lin YX et al., 2015), Quaternary deposit environment (Shi LF et al., 2009; Wang Q and Li CX, 2009; Xu QM et al., 2011; Yang JL et al., 2015), hydrogeology (Miao JJ et al., 2008; Yang YD et al., 2011), engineering geology (Wang LH et al., 2015), land subsidence (Bai JW and Niu XJ, 2010; Lyu XW et al., 2017; Guo HP et al., 2017), environmental geology (Li JF et al., 2010) and geothermic geology (Cheng WQ et al., 2012) of Tianjin and the surrounding areas. These preliminary works have provided the regional geological survey with detail geological data, and also lay the groundwork for preparation of the geologic map. The 1 ∶ 50 000 geologic map of the Huangzhuang map-sheet

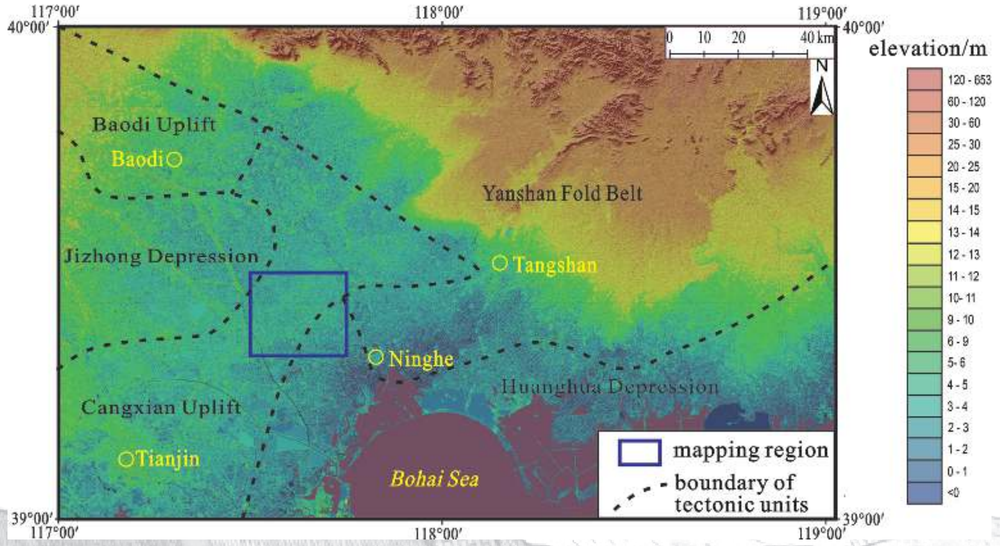

Fig. 1 Location map for geotectonics of the 1 ∶ 50 000 Huangzhuang map-sheet, Tianjin

(J50E004015) is one of the map-sheets for the 1∶50 000 regional geological survey that is continuously deployed by the Tianjin Geological Survey Center of China Geological Survey in the Luanhe Alluvial Fan-Delta Area. The 1∶50 000 regional geological survey was carried out and a spatial database of the geological map was built; having figured out the problems of the basic geological conditions restricting hydrogeology, engineering geology, environmental geology and hazardous geology and other such problems. This was based on systematical collecting, analyzing and utilizing of the existing areal geology, geophysical prospecting, chemical prospecting, remote sensing and other data in the map sheet; and by using digital mapping, remote sensing interpretation, drilling, comprehensive geophysical prospecting and many other technologies; as well as taking the Quaternary geologic structure and fault structure as key survey objects. All of this could help to support sustainable development of an important national economic zone, major project construction, geological and ecological environmental protection, and urban planning. The geologic map of the 1∶50 000 Huangzhuang map-sheet (J50E004015), Tianjin reflects the geological survey and research achievements obtained in the new round of regional geological surveys. These surveys explore and summarize methodology and achievement presentation of modern mapping technology in the plain area, which in turn provide basic support and innovative power to the improvement of the geological research level of the surveyed area, as well as innovating geological theory and the application of modern mapping technology. A simple list for the metadata of the geologic map database of the 1∶50 000 Huangzhuang map-sheet, Tianjin(Huang M et al., 2020) is shown in Table 1.

2 Data Acquisition and Processing

2.1 Data Acquisition

Data collection, remote sensing interpretation, digital elevation model (DEM) interpretation, geological route survey, artificial groove shaped drilling, scarp profile survey, Quaternary geological drilling, sample collection and test, and many other means were used for the data acquisition of the regional geological survey. Different survey methods were adopted for different purposes. For the purpose of ecological environmental protection; the Middle and Late Holocene stratum, and geological and geomorphic features were mainly surveyed. The means by which the survey was carried included remote sensing, digital elevation, artificial groove shaped drilling and scarp. For the purpose of hydrogeology; Late Cenozoic stratigraphic framework and stratigraphic texture feature were surveyed, and a 500 m-depth borehole was drilled. For the purpose of regional engineering geology; a Quaternary stratum was mainly surveyed, seven boreholes with a depth between 70–80 m depth and two boreholes with a depth of 20 m depth were drilled. The geographical base map used in data acquisition was provided by the National Geomatics Center of China, with a plotting scale of 1∶25 000, coordinated system of the 1980 Xi’an coordinated system, projection of planimetric rectangular coordinates and the coordinate unit in m, together with the 1985 national datum elevation.

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	Database of the 1∶50 000 Geological Map of Huangzhuang, Tianjin
Database (dataset) authors	Huang Meng, Tianjin Institute of Geological Survey Chen Xing, Tianjin Institute of Geological Survey Wang Li, Tianjin Institute of Geological Survey Ma Qingyun, Tianjin Institute of Geological Survey
Data acquisition time	2016−2018
Geographic area	117°30'−117°45' E, 39°20'−39°30' N
Data format	MapGIS
Data size	43.8 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	China Geological Survey project named 'Geological and mineral survey of the Fengning and Tianzhen area in the Yanshan—Taihang metallogenic belt' (DD20160042)
Language	Chinese
Database (dataset) composition	The geologic map database of the 1∶50 000 Huangzhuang map-sheet includes 4 datasets, i.e. basic element, comprehensive element, object element and independent element, a total of 23 catogories of data types. A dataset of the basic element is composed of the surface entity of the geological body, geological (boundary) line, sample, camera-shooting (photo), isotopic dating, borehole, river, lake, sea, shoreline of reservoir, etc. A dataset of the comprehensive element is a standard framework (inner framework). A dataset of the object element is composed by a stratigraphic unit of sedimentary (volcano) rocks, planar water, marsh and basic information of the map sheet. The independent element is the map embellishment, which includes a comprehensive histogram, map cutting profile, map embedding, legend, map set, etc

2.1.1 Remote Sensing Interpretation

Five image data sources of different time phases and type, i.e. TM (Thematic Mapper) image data of 1985, ASTER image data of 2002, Landsat-7 satellite data of 2003, Resource III satellite data of 2014 and Landsat-8 satellite data of 2016 were selected for remote sensing interpretation; for the purpose of multiband fusion interpretation. The processing and interpretation procedure of remote sensing data includes false color composite, geometric correction, data fusion, image embedding, remote sensing information extraction, interpretation mark establishing, explanation and verifying, etc. The geometric correction was rectified by using a polynomial method, taking the 1∶50 000 topographic map as a base map and control points were uniformly selected to conduct the ortho-rectification. There were no less than nine control points in each map-sheet and fitting precision of which to the ground control point was controlled within two pixels. Extraction of remote sensing information was mainly extraction of linear image information and massive image information. Visual interpretation was used for the interpretation of ancient course (Oxbow Lake), point bar, natural levee, crevasse splay, beach ridge, alluvial fan, depression and others; computer supervised classification was used as a main method and the visual interpretation was used as an auxiliary method, so as to interpret the Quaternary deposit, establish interpretation mark of microtopography, rickle lithology and other geologic bodies.

2.1.2 Interpretation of DEM

A 1：10 000 topographic map (1m contour interval) of the Tianjin Bureau of Surveying and Mapping in 2000 was selected as the DEM model data for extracting altitude data; after abnormal data of the original geomorphologic analysis was removed, then the DEM of a map-sheet was generated by using ArcGIS and the elevation precession could reach 0.2 m. DEM can truly reflect the features of landform and landform combination, which could also accurately reflect topographic feature, landform outline, terrain changing, surface cutting and other contents of different areas. Therefore, this can fully compensate the shortcomings of the geologic mapping of the Tianjin Binhai Plain that is a flat terrain, with little change in slope and landform that is hard to differentiate; so genetic type division and vertical geological structure study of superficial deposits could be conducted in more detail.

2.1.3 Geological Route Survey

The purpose of a geological route survey was to figure out the Quaternary geomorphologic and geological features, current status and spatial distribution of geological environment in the surveying area, and thus in order to plot the Quaternary geomorphologic and geologic map. The field geological route survey was conducted by using the Android Digital Mapping System (AoRGMap). Both the geological survey and collating process of field PRB follow the working guide and operating manual of '*Instructions for the Digital Geological Survey System'* (Li CL, 2011). In order to preliminarily build up the digital mapping (PRB) database, the geological observation points (P), geological boundaries (B) and the point and line data of the piecewise routes (R) were marked in the Digital Geological Survey System; the attribution; sediments and sedmentary tectonics of each observed point was input into the DGSS. In the geological route survey, the geological route should be perpendicular to the boundary of the key geological unit. Each geological unit was required to have at least 2–3 geological route controls. Mean workload was not adopted in the route space and point pitch, which were controlled within 1000– 3000 m according to the geological complexity. Key geologic body and regions with huge landform changes were tracked to a certain extent along their direction. Geological observation points were mainly deployed on the distribution area of the geological boundary and geological body, dividing line of the lithological boundary, geological boundary, important contact relation, different geomorphic units and micro-morphology units, as well as variation sections of soil and vegetation.

2.1.4 Artificial Groove Shaped Drilling

In the route survey, full hole coring drilling was conducted by using a groove shaped sampler and the 3–5 m superficies were surveyed. Superficies lower than 5 m are mainly Late Holocene deposits, which are key layers for studying Holocene evolution of the geological environment evolution. In addition to this, as the earth's key belt, the 3–5 m superficies are crucial for land utilization, groundwater recharge and environmental protection. Soil that was taken out via full hole coring using a groove shaped sampler was basically not disturbed, which could then be used for observing and studying constitute and structure of superficial unconsolidated deposit. This could also offer genetic type and other detail information of superficial unconsolidated deposit, playing a specific role in the control of the stratum boundary.

2.1.5 Scarp Profile Survey

In the geological route survey, the profile survey should be made at brickyards and other artificial outcrops, the selected plotting scale was generally 1：200. For geologic bodies whose diameter was greater than 20 cm were consequently layered; for those less than 20 cm but with special significance were emphatically described and highlighted in expression. The samples for ^{14}C and microcrystalline identification were collected at the profile and the relationship between the Quaternary geological body and geomorphic type was thus figured out; based on the material composition and geomorphic parts, the mapping unit was divided and depositional sequence established, thus to study the formation age of each Quaternary geological body, as well as the congruent relationship between them and the chronostratigraphies.

2.1.6 Quaternary Geological Drilling

Quaternary lithostratigraphy was divided by the Quaternary geological drilling and establishing the Quaternary chronostratigraphy, magnetostratigraphy, biostratigraphy, eventstratigraphy and climatostratigraphy sequence of the working area, in order to make a division and comparison of multiple stratigraphics, achieved by means of core description, sample collection and test work of a standard borehole system. The core description was all completed outdoors. The core was placed into a 10 cm diameter polyvinyl chloride (PVC) pipe, with a fresh face cut open, observed, recorded and researched color, material composition, structure, construction, basic sequence, contact relationship of strata, oxidoreduction features, biotic component (macrofossil) and others in detail. At the same time, paleomagnetism, ^{14}C dating, micropaleontology, comprehensive sample (chromaticity, carbonate and magnetic susceptibility) and other testing samples were systematically collected during drilling. When a borehole reached the designed depth, natural potential, apparent resistivity, gradient resistivity, natural gamma-ray logging were conducted. The operation of which was from bottom to top, automatically, continuously and constantly.

2.2 Construction Process of the Database

Construction process of the 1：50 000 geologic map database of the Huangzhuang map-sheet, Tianjin was conducted by strictly following a database building standard, i.e. '*Standard for spatial databases of digital geologic maps'* (DD 2006–06) and '*Instructions for the Digital Geological Survey System'* (Li CL, 2011). The construction process of the database is shown in Fig. 2.

2.2.1 Field Database of Geologic Mapping

Field database of geologic mapping includes field hand map library, general field map (PRB) library and sample library. The filed hand map library is the first-hand information obtained from field digital mapping; collections of the field route includes geological observation spot, the route between different points, geological boundary, sketch and pictures; indoor route collating includes a label of a geologic observation spot, picture, sketch and other embellishments and labels. Routes with completed PRB data will be added into the general

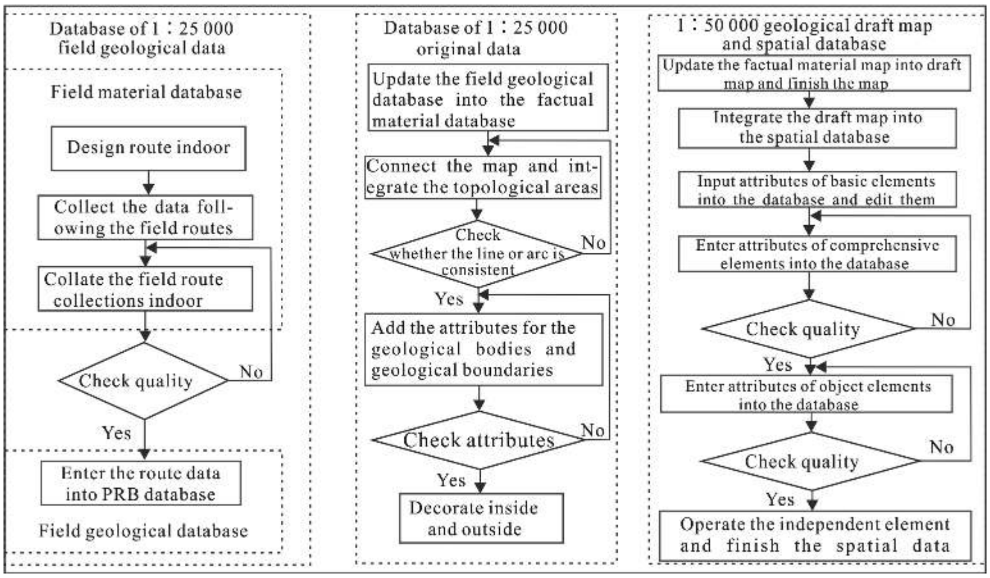

Fig. 2 Construction process chart of the 1∶50 000 geologic map database of the Huangzhuang map-sheet, Tianjin

field map library one by one, which are completed in the opened PRB library of the map-sheet, thus forming the general field map (PRB) library.

In order to ensure completeness, correctness and safety of data collection, quality inspection and data backup of the PRB data of the field geological route was conducted. The sample library includes all sample information of field work, i.e. sampling information, sample sending information and test achievements; among which, sampling information and sample sending information was input at the field database stage of the geologic mapping, and the test achievement was input at the map library stage of the actual material.

2.2.2 Map Library of Actual Material

The actual digital material map is an informative drawing that integrates primitiveness, comprehensiveness, visibility and the dynamics of PRB data in one; which is prepared on the background of the PRB map-sheet library. Database building of the actual material map was mainly focused on the editing of three documents, i.e. the geological polygon document (Geopoly.wp), geological line document (Geoline.wl) and geological point document (Geolabel.wt).

The detailed procedure was as follows: (1) Drew a geological boundary according to the geological route survey, artificial groove shaped superficial drilling, scarp profile survey and other data, as well as combining the remote sensing image and DEM image feature; (2) Processed topological relationships; (3) Assigned attributes to Geopoly.wp and Geoline.wl; (4) Designed and added personalized layers in accordance with the design documents and customer requirements.

2.2.3 Original Map for Compilation

The plotting scale of the original map, that was used for compilation, is 1∶50 000, which was developed on the basis of a 1∶25 000 actual material map. The merge of four 1∶25 000 actual material maps consequently led to the compilation of the original map for compilation, with the specific methodology as follows: (1) Connected the geological boundaries of two

1：25 000 map sheets at the borderline and integrated planar water within the map-sheet into the map and conducted a topology error-check, so as to ensure a correct topology relationship; (2) The surface entity of a geological body was formed after the geologic body's boundary topology was completed; by merging label points, the surface attribute of the 1：25 000 actual material map was inherited; (3) Marked the pixel of each geological body by using a geological code, embellish legend, figures outside the master map, chart, map profile and adjoining sheet. The embellishment should follow relevant standards and specifications, and comply with the publishing requirements for geologic maps, in order to ensure the normalization and standardization of the original map for compilation.

2.2.4 Spatial Database of the Geologic Map

Once the original map for compilation is checked and affirmed by experts, the next step is the construction stage of spatial database, which follows this specific methodology: (1) The original map for compilation is automatically merged into a spatial database and the spatial database feature data will automatically inherit any of the original map for compilation's partial content; (2) Check consistency of the map topology, expression of geological elements, map structure and other contents by using man-machine interaction means, thus making sure that it completely meets the requirements for geologic map and database building of spatial databases; (3) Supplement and type in the attribute data of the basic feature class; (4) Extract any comprehensive feature data and supplement the attribute data; (5) Extract any object features and supplement the attribute data; (6) Type in the attribute data of the object class.

2.2.5 The Quaternary Borehole Database

Ten Quaternary boreholes were constructed in this paper, the depths of which are between 20–500 m. The Quaternary borehole database was built separately during the construction process of the database. The exact database building method is as follows: (1) Build Quaternary borehole database under the PRB library interface of the map-sheet and then add the borehole data into the database by either typing or importing; (2) Based on the build-in database of the system, create Access databases for the logging curve, test result of paleomagnetism, test result of comprehensive sample, stratigraphic age, division of lithostratigraphy and other contents; (3) Embellish the map title, map head, table header, table body and other parts, in order to make the histograms presentable and practical. After the design is completed, the comprehensive histogram will then be created.

3 Description of Data Sample

The geologic map database of the 1：50 000 Huangzhuang map-sheet of Tianjin is composed of 4 element datasets, i.e. a basic element dataset, comprehensive element dataset, object element dataset and independent element dataset.

3.1 Basic Element Dataset

The basic element dataset of the 1：50 000 geologic map database of the Huangzhuang map-sheet of Tianjin includes the surface entity of the geological body (_GeoPolygon), geological (boundary) line (_GeoLine), sample (_Sample), camera-shooting (photo)

(_Photograph), isotopic dating (_Isotope), borehole (_Drillhole), shoreline (of river, lake, sea, reservoir) (_Line_Geography) etc.

Attributes of the surface entity of the geological body (_GeoPolygon) include identification number, original code, the surface entity of the geological body type code (geological code), geological body name, age, the lower age value, the upper age value, subtype identification, etc. as shown in Table 2. The surface entity of the geological body in the 1 ∶ 50 000 geologic map database of the Huangzhuang map-sheet of Tianjin includes two types, which are respectively sedimentary strata unit, and planar water and marsh.

The sedimentary strata unit can be divided into fluvial, delta and marine deposit. The fluvial deposit includes seven genetic types, i.e. the marginal bank, oxbow lake, natural levee, flooding basin, lakes and marsh; the delta deposit includes two genetic types, i.e. the delta front and distributary channel; the marine deposit includes four genetic types, i.e. the beach ridge, overbank fan and high tide flat desalination lagoon. The fluvial deposit is classified as the Qikou Formation, and the delta and marine deposit is classified as the Gaowan Formation.

The geological (boundary) line (_GeoLine) attribute includes element ID number, original code, code (geological code), type, left geological body code, right geological body code, interface trend, interface inclination, interface dip, etc. as shown in Table 3. The Huangzhuang map-sheet geologic map database includes two types of geological (boundary) lines i.e. unconformity and water contacting. The '*Standard for spatial databases of digital geologic maps'* (DD 2006–06) stipulates contact relations between Quaternary and old stratum, as well as Quaternary stratigraphic units, is unconformable contact. Therefore, the contact type between different sedimentary strata units in this database is all unconformable contact, and water contacting for any between planar water and sedimentary strata units.

The sample (_Sample) attribute includes element ID number, original code, No., type code, type name, rock name, subtype identification, etc., as shown in Table 4. Sample types in the geologic map database of the Huangzhuang map-sheet are all isotopic age samples, which were tested by using accelerator mass spectrometry (AMS) ^{14}C.

The camera-shooting (photograph) (_Photograph) attribute includes element ID number, original code, photo No., photo name, photo description, subtype, etc.

Table 2 Attribute table of surface entity of geological body

No.	Name of data item	Standard code	Data type	Example for content description
1	Identification number	*Feature_Id	Character	AJ50E004015000000049
2	Original code	Source_Id	Character	
3	Type code	*Feature_Type	Character	Qhq$r$s
4	Geological body name	Geobody_Name	Character	Marginal bank deposit of the Qikou Formation of Holocene
5	Era	Geobody_Era	Character	Qh
6	Lower age value/a.B.P	Geobody_Age1	Double	0
7	Upper age value/a.B.P	Geobody_Age2	Double	2 500
8	Subtype identification	Subtype	Integer	Stratigraphic unit of sedimentary (volcano) rocks

Note: $ denotes superscript.

Table 3 Attribute table of geological (boundary) line

No.	Name of data item	Standard code	Data type	Example for content description
1	Element ID number	*Feature_Id	Character	AJ50E004015000000158
2	Original code	Source_Id	Character	
3	Code	*Feature_Type	Character	02
4	Type	Boundary_Name	Character	Unconformity
5	Left geological body code	Left_Boundary_Code	Character	Qhq$l$v
6	Right geological body code	Right_Boundary_Code	Character	Qhq$r$s
7	Interface trend/°	Strike	Integer	330
8	Interface inclination/°	Dip_Direction	Integer	60
9	Interface dip/°	Dip_Angle	Integer	1

Note: $ denotes superscript.

Table 4 Attribute table of sample

No.	Name of data item	Standard code	Data type	Example for content description
1	Element ID number	*Feature_Id	Character	AJ50E004015000000004
2	Original code	Source_Id	Character	D0095_3
3	Sample No.	Sample_Code	Character	03
4	Sample type code	*Feature_Type	Character	TW
5	Sample type name	Sample_Name	Character	Isotopic age sample
6	Sample rock name	Rock_Name	Character	Cinereus clay
7	Subtype identification	Subtype	Integer	0

The isotopic dating (_Isotope) attribute includes element ID number, original code, sample No., sample name, age determination method, dating, unit and code of the determined geological body, determining and analyzing unit, determining and analyzing date, subtype identification, etc., as shown in Table 5.

The borehole (_Drillhole) attribute includes element identification, original code, drilling No., drilling depth, borehole depth of bed rock or target stratum, bed rock or target stratum lithology, bed rock or target stratum age, loose sedimentary layer age, stratified depth of loose sedimentary layer, loose sedimentary layer lithology, subtype identification, etc., as shown in Table 6. Boreholes in the geologic map database of the Huangzhuang map-sheet are all boreholes of unconsolidated formation and were not drilled through the bed rock. Based on the difference of target stratums, it can be divided into three types of boreholes, i.e. through the Holocene, Late Pleistocene and Quaternary, the depths of which are 20 m, 70–80 m and 500 m respectively, and the ages of the target stratum are respectively Qp_3, Qp_2 and N_2.

The shoreline (_Line_Geography) attribute of the rivers, lakes, seas and reservoirs includes original code of element ID number, pixel type, pixel name, subtype identification, etc.

3.2 Comprehensive Element Dataset

The comprehensive element dataset of the 1∶50 000 geologic map database of the

Table 5 Attribute table of isotopic dating

No.	Name of data item	Standard code	Data type	Description of data item
1	Element ID number	*Feature_Id	Character	AJ50E004015000000003
2	Original code	Source_Id	Character	D0095_2
3	Sample No.	Sample_Code	Character	QHZ09-^{14}C02
4	Sample name	Sample_Name	Character	Brown-grey clay
5	Age determination method	Measuring_Kinds	Character	Accelerator Mass Spectrometry (AMS) carbon-14 test
6	Dating/a B.P.	Age	Character	5 360 ± 30
7	Unit and code of the determined geological body	Geobody_Code	Character	Qhg$b$r
8	Determining and analyzing unit	Unit	Character	American BETA laboratory
9	Determining and analyzing date	Date	Character	2018-08-18
10	Subtype identification	Subtype	Integer	0

Note: $ denotes superscript.

Table 6 Attribute table of borehole

No.	Name of data item	Standard code	Data type	Description of data item
1	Element ID number	*Feature_Id	Character	AJ50E004015000000002
2	Original code	Source_Id	Character	QHZ04
3	Borehole No.	Zk_Code	Character	QHZ04
4	Borehole depth/m	Zk_Depth	Float	70
5	Borehole depth of bed rock or target stratum /m	Rock_Depth	Float	70
6	Bed rock or target stratum lithology	Rock_Type	Character	Grayish yellow clay, silty clay and clayey silt, with much more caliche nodule and hydromorphic plaque
7	Bed rock or target stratum age	Base_Bed_Era	Character	Qp@2
8	Loose sedimentary layer age	Loose_Lay_Era	Character	Qp@2
9	Stratified depth of loose sedimentary rock/m	Loose_Lay_Thickness	Float	70
10	Loose sedimentary layer lithology	Loose_Lay_Lithology	Character	Grey, dark grey, claybank, grayish yellow clay, silty clay, clayey silt, silt, fine sand and medium sand
11	Subtype identification	Subtype	Integer	0

Note: @ denotes subscript.

Huangzhuang map-sheet of Tianjin is a standard picture frame (inner picture frame) (_MAP_FRAME.WL), the attributes of which include picture name, map-sheet code, plotting scale, coordinated system, elevation system, left longitude, lower latitude, cartographic unit, etc.

3.3 Object Element Dataset

The object element dataset of the 1：50 000 geologic map database of the Huangzhuang map-sheet of Tianjin is composed of sedimentary (volcano) rock stratigraphic unit (_Strata), planar water and marsh (_Water_Region) and the basic information of map-sheet.

The attributes of the sedimentary (volcano) rock stratigraphic unit (_Strata) include element classification (geological code), stratigraphic unit name, stratigraphic unit symbol (code for the surface entity of the geological body), stratigraphic unit age, rock association name, main rock association color, main deposit tectonics of rock stratum, fossil organism belt or biological combination, strata thickness, ore-bearing potential, subtype identification, etc., as shown in Table 7. The name of the sedimentary (volcano) rock stratigraphic unit of the Huangzhuang map-sheet geologic map database is a combination of 'age + rock stratigraphic unit + genetic type', e.g. the Holocene Gaowan Formation, beach ridge deposit (Qhg^{br}) has a total of 13 stratigraphic units, the age of which are all Holocene (Qh).

The planar water (_Water_Region) attribute includes element classification code, pixel type, pixel name, pixel feature, subtype identification, etc.

The basic information (_Sheet_Mapinfo) attribute of the map-sheet includes geologic map No., map name, plotting scale, coordinated system, elevation system, left longitude, right longitude, upper latitude, lower latitude, mapping method, surveying unit, map-sheet acceptance unit, scoring grade, completed time, publishing time, data source and data acquisition date.

3.4 Independent Element Dataset

The independent element dataset of the 1：50 000 Huangzhuang map-sheet geologic map database of Tianjin is mainly the map embellishment, which is composed of a comprehensive

Table 7 Attribute table of sedimentary (volcano) rock stratigraphic unit

No.	Name of data item	Standard code	Data type	Description of data item
1	Element classification (geological code)	*Feature_Type	Character	Qhg$b$r
2	Stratigraphic unit name	Strata_Name	Character	Holocene Gaowan Formation and beach ridge deposit
3	Stratigraphic unit symbol (code for the surface entity of the geological body)	Strata_Code	Character	Qhg$b$r
4	Stratigraphic unit era	Strata_Era	Character	Qh
5	Rock association name	Association_Name	Character	Clayey silt, silt, silty clay, conch contained shell and debris
6	Main rock association color	Color	Character	Main color of the rocks
7	Main deposit structures of rock stratum	Sedi_Structure	Character	cross bedding, parallel bedding, lentoid bedding and nervation bedding
8	Fossil organism belt or biological combination	Assemblage_Zone	Character	Foraminifer, marine ostracoda and clams
9	Strata thickness/m	Strata_Thickness	Character	0–3.0
10	Ore-bearing potential	Commodities	Character	
11	Subtype identification	Subtype	Integer	

Note: $ denotes superscript.

histogram (COLOUM_SECTION), map cutting profile (MAP_PROFILE), map cutting profile line (PROFILE), map embedding (XT), Quaternary isobath (DEPTH), hidden fault (HIDDEN_FAULT), paleocoast line (PALEOCOAST LINE), legend (LEGEND), map set (MAP_SHEET), duty table (DUTY_TABLE), label (INDICIA), etc. The main contents of the subdatasets are as listed below.

The comprehensive histogram (COLOUM_SECTION) subdataset includes a multi-stratigraphic feature of a standard geological borehole QHJ01 and a vertical stratigraphic structure feature of a deposit with different genetic types in the superficies.

The map cutting profile (MAP_PROFILE) subdataset includes a 3D stratigraphic structure feature formed from the Late Pliocene (500m lower).

The map embedding (XT) subdataset includes a geotectonic position of the map-sheet, Pre-Cenozoi geologic map of bed rocks, evolution diagram of lithofacies paleogeography since the Pliocene, partition map of antifouling performance of underground water, contour map of surface subsidence, mollisol distribution map of the Gaowan Formation in the Holocene, earthquake-induced liquefaction of potential saturated sand (power) distribution map, and stability evaluation map of the regional earth crust.

The Quaternary isobath (DEPTH) subdataset is a Quaternary variation feature of the bottom boundary burial depth within the map-sheet.

The hidden fault (HIDDEN_FAULT) subdataset is the distribution feature of the main fault within the map-sheet.

The paleocoast line (PALEOCOAST LINE) subdataset is the paleocoast line position of different transgression periods since the Late Pleistocene. The coastline positions of three different periods could be identified in transgression period I, which are respectively 5.5 ka.B.P, 4.0 ka.B.P and 2.5 ka.B.P up til now. However, only the coastline position of the maximum transgression could be identified in transgression period II.

4 Data Quality Control

A field geological investigation precision of the 1：50 000 geologic map of the Huangzhuang map-sheet of Tianjing entirely follows *the 'General principle for regional geological surveys* (1：50 000)' (DZ/T 0001), '*Operating instructions for regional geological surveys of 1:50 000 coverage areas (Trail)'* and other related specifications. The survey precision meets normative requirements of regional geological surveys. Both the field PRB geological survey route and collating procedure follow guides and instructions of '*Field data acquisition of regional geological surveys'*. During the implementation process, PRB data quality is monitored; conformity established between digitized and original data, as well as checking the digitized precision; and ensuring all geological data has a backup of the original data and periodical backups. The construction of the database completely follows the '*Standard for spatial database of digital geologic maps'* (DD 2006–06), '*Quality inspection and evaluation of geological data'* (DD 2006–07) and related specifications.

The rate for self-check and mutual-check of the original field data during the whole operating process is 100%, more than 30% of which was checked by the project team, thus meeting the quality management requirements of geological survey projects. During the Quaternary geological drilling, a drilling rig team was founded specifically for this purpose, with the intention of reinforcing the quality management of drilling construction. Furthermore, technical experts were employed for regular inspections during drilling construction and an overall inspection over each original record and technical data was conducted. For the basis of inner inspection of the project, we cooperated with the production supervisor of the company and the higher management institution to carry out annual quality inspections, both indoors and outdoors, and solved geological problems within the map-sheet according to the requirements of the inspection group promptly.

The spatial database of the 1∶50 000 geologic map of the Huangzhuang map-sheet of Tianjing had passed the acceptance organized by the Tianjin Geological Survey Center, China Geological Survey from 25th to 27th, January, 2019, which was appraised as "Excellent".

5 Data Value

In the geological and geomorphic survey of the 1∶50 000 geologic map of the Huangzhuang Map Sheet of Tianjin, multi-date remote sensing and DEM with 0.2 m precision was fully used, through the combination of groove shaped drilling and route surveying, with the superficial deposit divided into two deposit systems, i.e. river and transgression. The transgression was developed in the mid-Holocene, forming a delta and regressive deposit. The delta deposits are distributed at the northern region of the map-sheet, which could be subdivided into a delta front, delta branch channel and other deposits; the regression deposits are distributed in the central and at the southern regions of the map-sheet, which were developed by regression and transformed the delta deposits, which can be subdivided into a beach ridge, overbank fan, high tide flat, lagoon and other deposits (Xu QM et al., 2020). The fluvial deposit system is distributed in the northeastern and northwestern regions of the map-sheet, which includes a river way, embankment, flooding and other deposits, and cutting and transforming regression deposits. On the basis of dividing genetic types in detail, the lithological association and vertical evolution features of the superficial deposit, for different reasons, are summarized. It provides detailed basic geological support to the analysis that rainfall infiltrates and supplements groundwater resources, from the aspects of hydrogeology and environmental protection of water sources (Meng SH et al. 2011). On the basis of presentations of alluviation, alluvial marine deposit, marine deposit and other traditional genetic types in the past, the mapping unit is further refined in the geologic map of Huangzhuang map-sheet and a typical borehole histogram is selected to indicate the vertical structure of the superficial deposit caused by superficial reasons. In the meantime, the geologic map of bed rocks, lithofacies paleogeography evolution since the Neogene, antifouling performance of underground water, surface subsidence isoline, mollisol distribution scope, earthquake-induced liquefaction of potential saturated sand (power) soil, stability evaluation of regional crust and other maps are presented on the geologic map as an embedded map, consequently innovating map presentation of geologic maps.

Through the construction of a geological standard borehole (QHJ01); a division and comparison for rock, age, climate, biology, magnetism and other multi stratums was conducted in a deep geological survey; stratigraphic dividing sign was summarized and stratigraphic framework since the Late Pliocene was established. By combining the constructed Quaternary control, hydrogeological borehole data was effectively collected and many profiles were drawn, thus reflecting 3D stratigraphic structure features since the Late Pliocene. From the Late Pliocene to Middle Pleistocene, the ancient Luanhe alluvial apron-estuary delta depositary system developed in the map-sheet, and extended towards the east from the west, is the target stratum of the water source survey. Spatial distribution and material composition was figured out, offering basic data for analyzing storage space and the migration pathway of underground water (Wang JB, 2013). Mollisol deformation and earthquake-induced liquefaction of saturated sand (power) soil and other environmental engineering geological problems are present in the map-sheet. However, the spatial distribution and material composition of the Period II transgression, and palaeochannel deposit that had been developed since the Late Pleistocene have now been figured out; and the distribution of mollisol and earthquake-induced liquefaction of saturated sand (power) soil has also been preliminarily summarized. Thereby providing hydrogeologists, engineers, environmentalists and geologists with detailed geological data to further survey and study such problems (Pei YD and Wang GM, 2016).

Based on the acquired geophysical prospecting, drilling and other data, we basically worked out the geologic structure of hidden bedrocks, and then drew up a geologic map of bed rocks, plotted a spatial distribution of the Cambrian-Ordovician Karst thermal reservoir, which provides fundamental geological data for resource surveying, and the development and utilization of deep geothermal energy (Liu J et al. 2012).

6 Conclusion

(1) The 1∶50 000 geologic map of the Huanghzhuang map-sheet of Tianjin and the deep geological structure was systematically summarized. This was achieved through the systematical collection, analysis and utility of existing areal geology, geophysical prospecting, chemical prospecting, remote sensing and other data in the map-sheet. Late Cenozoic stratums of different depths were surveyed and studied via different precisions and methods using digital mapping, remote sensing interpretation, drilling, comprehensive geophysical prospecting and many other technologies. Furthermore, the methodology for geological surveying and innovative geologic map presentation of low coastal plain coverage areas was helped to play a demonstrating role for regional geological surveys of the coverage area.

(2) A spatial database of the 1∶50 000 geologic map of the Huangzhuang map-sheet of Tianjin was established according to the standards and specifications for digital geologic maps through field surveys, indoor analysis and studies, and the integration of results. It includes four datasets, i.e. basic element, comprehensive element, object element, and independent element, totaling 23 catogories of data types, involving the surface entity of the geological body, geological (boundary) line, sample, camera-shooting (photo), isotopic dating, borehole, stratigraphic unit of sedimentary (volcano) rocks, comprehensive histogram, map cutting

profile, map embedding, etc. All of this fully reflects the study achievements acquired in the map-sheet.

(3) The 1∶50 000 geologic map spatial database of the Huangzhuang map-sheet of Tianjin provides detailed and basic geological data for geological environmental protection, natural resource management, as well as environmental, engineering and hydrogeological surveying, and further supports the sustainable development of an important national economic zone, major construction projects, geological environmental protection, urban planning and ecological environmental protection.

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